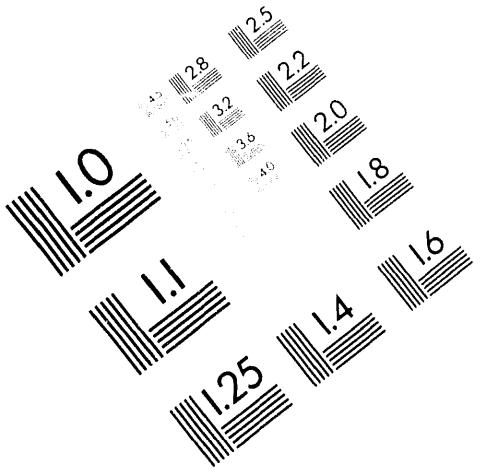

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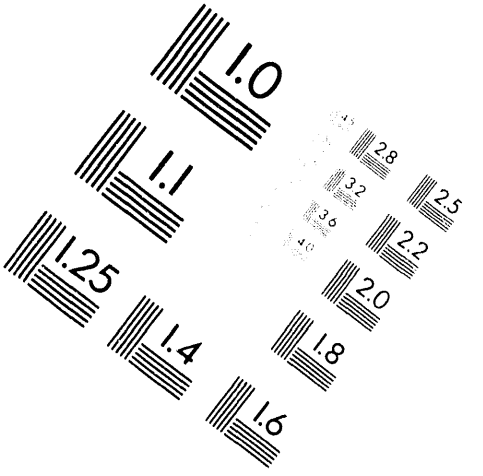

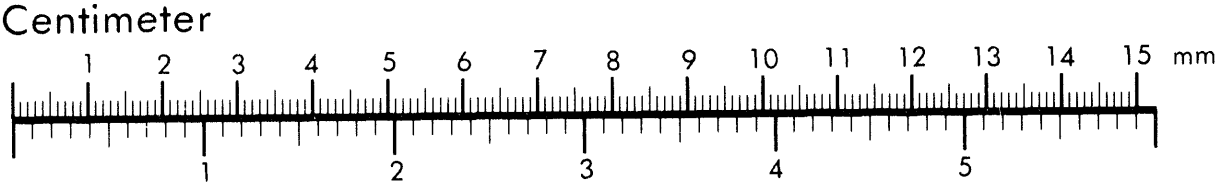

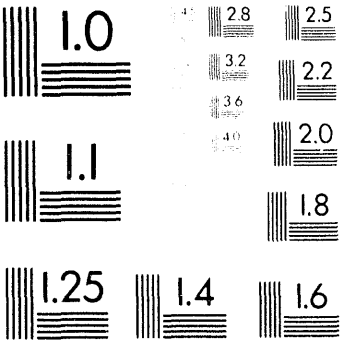

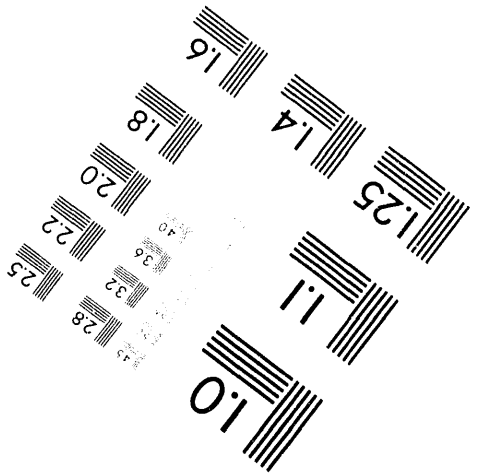

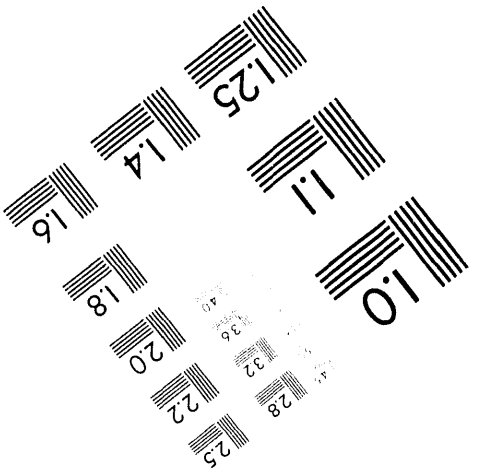

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PRRC 94-15

FIELD VERIFICATION OF CO_2-FOAM

DOE Grant No. DE-FG21-89MC26031

New Mexico Petroleum Recovery Research Center
New Mexico Institute of Mining and Technology
Socorro, NM 87801
(505)835-5142

Contract Date:	September 29, 1989
Anticipated Completion Date:	March 28, 1995
Funding for FY 1994:	-0- (No-cost extension)

Principal Investigator:	F. David Martin
Co-Principal Investigators:	John P. Heller
	William W. Weiss

Project Officer:	Royal Watts
	Morgantown Energy Technology Center

Reporting Period: January 1 to March 31, 1994

DISCLAIMER

OBJECTIVES

The objectives of this cooperative industry-university-government project are to (1) transfer promising laboratory research to a field demonstration test, (2) provide research support to design and implement the test, and (3) evaluate the use of foam for mobility control and fluid diversion in a field CO_2 flood.

SUMMARY OF TECHNICAL PROGRESS

The East Vacuum Grayburg/San Andres Unit (EVGSAU), operated by Phillips Petroleum Company (PPCo), is the site selected for a comprehensive evaluation of the use of foam for improving the effectiveness of a CO_2 flood. The Petroleum Recovery Research Center (PRRC), a division of the New Mexico Institute of Mining and Technology (NMIMT), is providing laboratory and research support for the project. The project that began in 1989 is jointly funded by the EVGSAU Working Interest Owners (WIO), the U.S. Department of Energy (DOE), and the State of New Mexico. A Joint Project Advisory Team (JPAT) composed of WIO technical representatives from several major oil companies provides input, review, and guidance for the project. During this quarter, a twelve-month no-cost time extension was granted by the DOE. This extension will allow sufficient time to evaluate a second foam test.

FIELD FOAM TESTS

The favorable production responses resulting from the first foam injection test are described in our previous progress reports. Based on these favorable responses, a second foam test was initiated in May

1993 in the same injection well (3332-001) used for the first foam test. However, facilities problems have delayed the completion of the second test in Well 3332-001.

The foam injection test planned for early 1994 has been delayed due to a waterline leak on the line directly connected to the foam injector. The foam injector was on a CO_2 cycle for about three months while the waterline was out of service. A profile was taken during CO_2 injection and a bottomhole pressure will be taken in early April. The repair should be finished soon and the well switched back to water by mid-April. The injection pressure during water injection will be allowed to stabilize before any surfactant is injected. When the foam injection test begins, CO_2 will be injected for twelve days prior to any surfactant to test for residual effects. Then surfactant will be started at 1000 ppm for three to five days and followed with CO_2 for an unspecified time frame. This is in contrast to the previous foam tests, in which 2500 ppm surfactant was used, and in which five "rapid SAG" cycles of three days of surfactant injection was followed by twelve days of CO_2 injection. The amount of CO_2 in this new phase will depend on the injection well response to surfactant injection. In other words, surfactant will be injected followed by CO_2, and the injection pressure response due to foam generation will be observed. As this pressure response diminishes, due to either the foam moving away from the wellbore or the foam drying out from the continued injection of CO_2, then another surfactant slug will be injected. Data that will be gathered include a few flowing bottomhole pressures during CO_2 injection and a few profiles late in the surfactant injection period. The goal will be to determine the minimum amount of surfactant needed to control the offending producing well that has experienced CO_2 breakthrough.

TECHNOLOGY TRANSFER ACTIVITIES

Two technical papers related to the EVGSAU were presented at the 1994 SPE Permian Basin Conference in Midland, TX, March 16-18. Paper SPE 27675, entitled "Laboratory Flow Tests Used to Determine Reservoir Simulator Foam Parameters for EVGSAU CO_2 Foam Pilot," presented results of laboratory foam tests that will be used to determine foam parameters for use in foam-flood reservoir simulators. In paper SPE 27712, entitled "Automatic History Matching for an Integrated Reservoir Description and Improving Oil Recovery," static (geologic) and dynamic (production history) field data from the EVGSAU were used to obtain a reservoir description by an automatic history matching algorithm using the simulated annealing method. The reservoir description resulted from the inverse problem solution that was previously presented in paper SPE 26478 (1993 Annual Meeting, Houston). This reservoir description was then used in paper SPE 27712, which is a numerical "what if" experiment examining the outcome of continued waterflooding (no CO_2 flood) coupled with targeted infill drilling in the foam pilot area.

Three technical papers related to the EVGSAU were prepared for the SPE/DOE Ninth Symposium on Improved Oil Recovery that will be held in Tulsa, OK on April 17-20, 1994: paper SPE 27785, entitled "CO_2 Foam Field Verification Pilot Test at EVGSAU: Phase IIIA - Surfactant Performance Characterization and Quality Assurance;" paper SPE 27786, entitled "CO_2 Foam Field Verification Pilot Test at EVGSAU: Phase IIIB: Project Operations and Performance Review;" and paper SPE 27798, entitled "CO_2 Foam Field Verification Pilot Test at EVGSAU: Phase IIIC - Reservoir Characterization and Response to Foam Injection." In addition, a paper entitled "Reservoir Characterization by Inverse Modeling" was prepared for presentation at the Eighth International Conference of the International

Association for Computer Methods and Advances in Geomechanics at the College of Engineering, West Virginia University, Morgantown, WV, May 22-28, 1994.

RESERVOIR SIMULATION STUDIES

The EVGSAU reservoir simulation studies conducted at the University of Houston have been completed. During this quarter, a final report covering these studies was submitted by Dr. John Killough. This report has been sent to PPCo and will be disseminated to the JPAT members for comments.

At the PRRC, work has also been conducted on incorporating CO_2-foam features into reservoir simulators. The reservoir simulators used in this work include a multi-component pseudo-miscible reservoir simulator, MASTER (Miscible Applied Simulation Techniques for Energy Recovery), obtained from the Department of Energy and a compositional reservoir simulator, UTCOMP, provided by the University of Texas at Austin.

By utilizing the tracer features in UTCOMP, a foam model is developed. The surfactant solution movement is tracked by treating the surfactant solution as a water tracer without the addition of a surfactant-solution conservation equation into UTCOMP. The tracer adsorption model has been modified to account for the adsorption isotherm. Instead of using a mechanistic, bubble-population-balance approach to calculate the mobility of the gas-foam phase, the foam model reads as input the foam-resistance-factor data as lookup tables. The resistance factor is treated as a function of interstitial velocity, gas-liquid ratio, and surfactant concentration based on laboratory test results. The mobility of the gas-foam phase is calculated after the foam resistance factor is determined from lookup tables. The

coding for the addition of foam features into UTCOMP has been completed. Program testing and validation is our current emphasis.

The major modifications that were made to MASTER include (1) the addition of two conservation equations to permit simulation of surfactant solution and foam bubble, (2) the addition of an algorithm to calculate the mobility of gas-foam phase, and (3) the addition of a foam-resistance-factor table-lookup option similar to the one that has been incorporated into UTCOMP. In this new foam-flood simulator using MASTER, the mobility of gas-foam phase can be calculated by two approaches. The first approach involves using the foam-bubble population balance equation and the second approach is the foam-resistance-factor table-lookup option. The foam features can be easily bypassed, giving essentially the MASTER model, which can be used to simulate a wide range of immiscible-to-miscible gas-injection recovery processes. In addition, the simulator can be used to simulate most of the common primary and secondary recovery mechanisms by bypassing both the foam and miscible features in the model. Current emphasis is on the validation and testing of the program.

The foam models incorporated into MASTER and UTCOMP will be modified based upon the responses obtained during the EVGSAU field test. The predictions of field performance from both simulators will be compared with the results from commercial reservoir simulators during and after the field test.

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